

EL023RH-1

NON-PROVISIONAL PATENT APPLICATION

## TITLE

10        **AN ELECTROLYTIC AND ELECTROLESS PROCESS FOR TREATING  
METALLIC SURFACES AND PRODUCTS FORMED THEREBY**

15        The subject matter herein claims benefit of prior filed U.S. Patent  
Application Serial No. 60/310,006, filed on August 03, 2001 and entitled "An  
Electrolytic And Electroless Process For Treating Metallic Surfaces and Products  
Formed Thereby"; the disclosure of which is hereby incorporated by reference.

## FIELD OF THE INVENTION

20        The instant invention relates to a process for forming a deposit on the  
surface of a metallic or conductive surface. The process employs a process to  
deposit, for example, a mineral containing coating or film upon a metallic, metal  
containing or an electrically conductive surface.

## BACKGROUND OF THE INVENTION

25        Silicates have been used in electrocleaning operations to clean steel, tin,  
among other surfaces. Electrocleaning is typically employed as a cleaning step  
prior to an electroplating operation. Usage of silicates as cleaners is described in  
"Silicates As Cleaners In The Production of Tinplate" is described by L.J. Brown  
in February 1966 edition of Plating; European Patent No. 00536832/EP B1  
30        (Metallgesellschaft AG); U.S. Patent Nos. 5,902,415, 5,352,296 and 4,492,616.

Processes for electrolytically forming a protective layer or film by using an  
anodic method are disclosed by U.S. Patent No. 3,658,662 (Casson, Jr. et al.), and  
United Kingdom Patent No. 498,485.

35        U.S. Patent No. 5,352,342 to Riffe, which issued on October 4, 1994 and is  
entitled "Method And Apparatus For Preventing Corrosion Of Metal Structures"  
that describes using electromotive forces upon a zinc solvent containing paint;  
hereby incorporated by reference. U.S. Patent Nos. 5,700,523, and 5,451,431; and  
German Patent No. 93115628 describes a processes for using alkaline  
metasilicates to treat metallic surfaces.

40        The disclosure of each of the previously identified references is hereby  
incorporated by reference.

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## SUMMARY OF THE INVENTION

The instant invention solves problems associated with conventional practices by providing an electroless or electrolytic process for treating metallic surfaces. The process employs a medium comprising at least one oxygen containing water soluble compound having a controlled and predetermined concentration, temperature and pH wherein the metallic surface is at least partially corroded or solubilized. As a result, the medium interacts with the metallic surface to form a new or modified surface having one or more improved properties.

The inventive process can form a surface comprising a mineral layer comprising an amorphous matrix surrounding or incorporating crystals upon the substrate. The characteristics of the mineral layer are described in greater detail in the copending and commonly assigned patent applications listed below.

A metallic surface that is treated (e.g., forming the mineral layer) by the inventive process can possess improved corrosion resistance, increased electrical resistance, heat resistance, flexibility, resistance to stress crack corrosion, adhesion to sealer, paints and topcoats, among other properties. The improved heat resistance broadens the range of processes that can be performed subsequent to forming the inventive layer, e.g., heat cured topcoatings, stamping/shaping, riveting, among other processes. The corrosion resistance can be improved by adding a dopant to the silicate medium, using a rinse and/or applying at least one sealer/topcoating.

The inventive process is a marked improvement over conventional methods by obviating the need for solvents or solvent containing systems to form a corrosion resistant layer, e.g., a mineral layer. In contrast, to conventional methods the inventive process can be substantially solvent free. By "substantially solvent free" it is meant that less than about 5 wt.%, and normally less than about 1 wt.% volatile organic compounds (V.O.C.s) are present in the electrolytic environment.

The inventive process is also a marked improvement over conventional methods by reducing, if not eliminating, chromate and/or phosphate containing compounds (and issues attendant with using these compounds such as waste disposal, worker exposure, among other undesirable environmental impacts). While the inventive process can be employed to enhance chromated or phosphated surfaces, the inventive process can replace these surfaces with a more environmentally desirable surface. The inventive process, therefore, can be "substantially chromate free" and "substantially phosphate free" and in turn produce articles that are also substantially chromate (hexavalent and trivalent) free and substantially phosphate free. The inventive process can also be substantially free of heavy metals such as chromium, lead, cadmium, barium, among others. By substantially chromate free, substantially phosphate free and substantially heavy metal free it is meant that less than 5 wt.% and normally about 0 wt.% chromates,

5 phosphates and/or heavy metals are present in a process for producing an article or the resultant article.

#### CROSS REFERENCE TO RELATED PATENTS AND PATENT APPLICATIONS

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The subject matter of the instant invention is related to copending and commonly assigned WIPO Patent Application Publication No. WO 98/33960, Non-Provisional U.S. Patent Application Serial Nos. 08/850,323 (Now U.S. Patent No. 6,165,257); 08/850,586 (Now U.S. Patent No. 6,143,420); and 09/016,853 (now allowed), filed respectively on May 2, 1997 and January 30, 1998; and serial numbers 08/791,337 (now U.S. Patent No 5,938,976), filed on January 31, 1997, in the names of Robert L. Heimann et al., as a continuation in part of Serial No. 08/634,215 (filed on April 18, 1996) in the names of Robert L. Heimann et al., and entitled "Corrosion Resistant Buffer System for Metal Products", which is a continuation in part of Non-Provisional U.S Patent Application Serial No. 08/476,271 (filed on June 7, 1995) in the names of Heimann et al., and corresponding to WIPO Patent Application Publication No. WO 96/12770, which in turn is a continuation in part of Non-Provisional U.S. Patent Application Serial No. 08/327,438 (filed on October 21, 1994), now U.S. Patent No. 5,714,093.

25 The subject matter of this invention is related to Non-Provisional Patent Application Serial No. 09/016,849 (Attorney Docket No. EL004RH-1), filed on January 30, 1998 and entitled "Corrosion Protective Coatings". The subject matter of this invention is also related to Non-Provisional Patent Application Serial No. 09/016,462 (Attorney Docket No. EL005NM-1), filed on January 30, 1998 and entitled "Aqueous Gel Compositions and Use Thereof" (now U.S. Patent No. 6,033,495).

30 The subject matter of this invention is also related to Non-Provisional Patent Application Serial No. 09/814,641 (Attorney Docket No. EL008RH-6), filed on March 22, 2001, and entitled "An Energy Enhanced Process For Treating A Conductive Surface And Products Formed Thereby" (and corresponds to PCT Patent Application Serial No. PCT/US01/09293), and Non-Provisional Patent Application Serial No. \_\_\_\_\_ (Attorney Docket No. EL022RH-1), filed on August 03, 2002 and entitled "An Electroless Process For Treating Metallic Surfaces And Products Formed Thereby", and Serial No. \_\_\_\_\_ (Attorney Docket No. EL021RH-1), filed on August 03, 2002 and entitled "An Electroless Process For Treating Metallic Surfaces And Products Formed Thereby".

40 The disclosure of the previously identified patents, patent applications and publications is hereby incorporated by reference.

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## DETAILED DESCRIPTION

The instant invention relates to a process for depositing or forming a beneficial surface (e.g., a mineral containing coating or film) upon a metallic surface. The process contacts at least a portion of a metal surface with a medium comprising at least one oxygen containing water soluble compound, e.g., containing soluble mineral components or precursors thereof, having controlled concentration, temperature and pH wherein the metal surface is at least partially corroded or solubilized. By "oxygen containing water soluble compound" it is meant to refer to at least one member selected from the group of borates, aluminates, zirconates, titanates, molybdates, tungstenates, stannates, nitrates, sulfates, vanadates, cerium hydrates, water soluble manganese and magnesium compounds, nickel compounds, cobalt compounds, among other oxygenated water soluble compounds capable of interacting with a metal surface. By "mineral containing coating", "mineralized film" or "mineral" it is meant to refer to a relatively thin coating or film which is formed upon a metal surface wherein at least a portion of the coating or film comprises at least one metal containing mineral, e.g., an amorphous phase or matrix surrounding or incorporating crystals comprising a zinc disilicate. Mineral and Mineral Containing are defined in the previously identified Copending and Commonly Assigned Patents and Patent Applications; incorporated by reference.

By "metal containing", "metal", or "metallic", it is meant to refer to sheets, shaped articles, fibers, rods, particles, continuous lengths such as coil and wire, metallized surfaces, among other configurations that are based upon at least one of metals and alloys including a metal having a naturally occurring, or chemically, mechanically or thermally modified surface. Typically a naturally occurring surface upon a metal will comprise a thin film or layer comprising at least one oxide, hydroxides, carbonates, sulfates, chlorides, among others. The naturally occurring surface can be removed or modified by using the inventive process.

The metal containing surface refers to a metal article or body as well as a non-metallic member having an adhered metal or conductive layer. While any suitable surface can be treated by the inventive process, examples of suitable metal surfaces comprise at least one member selected from the group consisting of galvanized surfaces, sheradized surfaces, zinc, iron, steel, brass, copper, nickel, tin, aluminum, lead, cadmium, magnesium, alloys thereof such as zinc-nickel alloys, tin-zinc alloys, zinc-cobalt alloys, zinc-iron alloys, among others. If desired, the mineral layer can be formed on a non-conductive substrate having at least one surface coated with a metal, e.g., a metallized polymeric article or sheet, ceramic materials coated or encapsulated within a metal, among others. Examples of metallized polymer comprise at least one member selected from the group of polycarbonate, acrylonitrile butadiene styrene (ABS), rubber, silicone, phenolic, nylon, PVC, polyimide, melamine, polyethylene, polypropylene, acrylic, fluorocarbon, polysulfone, polyphenylene, polyacetate, polystyrene, epoxy, among

5 others. Conductive surfaces can also include carbon or graphite as well as  
conductive polymers (polyaniline for example).

10 The metal surface can possess a wide range of sizes and configurations,  
e.g., fibers, coils, sheets including perforated acoustic panels, chopped wires,  
drawn wires or wire strand/rope, rods, couplers (e.g., hydraulic hose couplings),  
fibers, particles, fasteners (including industrial and residential hardware), brackets,  
nuts, bolts, rivets, washers, cooling fins, stamped articles, powdered metal articles,  
among others. The limiting characteristic of the inventive process to treat a metal  
surface is dependent upon the ability of the surface to be contacted with the  
inventive medium.

15 The inventive process can be operated on a batch or continuous basis. The  
type of process will depend upon the configuration of the metal being treated. The  
contact time within the medium ranges from about 10 seconds to about 50 minutes  
and normally about 1 to about 15 minutes. The inventive process can be practiced  
in any suitable apparatus. Examples of suitable apparatus comprise a conventional  
20 barrel dip apparatus.

The medium can be a fluid bath, gel, spray, among other methods for  
contacting the substrate with the medium. Examples of the medium comprise a  
bath containing at least one oxygen containing water soluble compound, and a  
thickener, among others. The bath can comprise any suitable polar carrier such as  
25 water, alcohol, ethers, among others. Normally, the bath comprises at least one  
water-soluble compound and de-ionized water and optionally at least one dopant  
(e.g. a chloride). Typically, the at least one dopant is water soluble or dispersible  
within an aqueous medium.

The medium typically has a basic pH. Normally, the pH will range from  
30 greater than about 9 to about 13 and typically, about 10 to about 11. The pH of the  
medium can be monitored and maintained by using conventional detection  
methods. Alternatively, the medium can have an acidic pH. The selected pH will  
depend upon whether the metal surface is at least partially dissolved (or  
solubilized). That is, the inventive process employs a medium that is at least  
35 somewhat corrosive to the metal surface in order to enhance an interaction  
between the medium and the metal.

The medium is normally aqueous and can comprise at least one water  
soluble or dispersible compound in an amount from greater than about 0 to about  
40 wt.%, usually, about 3 to 15 wt.% and typically about 10wt.%. The medium is  
40 also normally substantially free of heavy metals, chromates and/or phosphates.

The temperature of the medium can be controlled to optimize the  
interaction between the medium and a metal surface. Normally, the temperature  
will range from about 50C to at least about 100C and typically about 80 to 100C.  
This temperature can be maintained by using conventional heaters and related  
45 control systems.

The chemical and/or physical properties of the medium can be affected by  
exposing the medium to a source of electrical or magnetic energy. For example,

5 the bath can be exposed to a source of energy such as the electrical current described in copending and commonly assigned U.S. Serial Nos. 09/824,641; hereby incorporated by reference. Such exposure can improve the interaction between the medium and the metal surface, partially polymerize the medium, modify the metal to oxygen ratio, concentrate the medium, among other desirable  
10 properties.

The medium can be modified by adding water/polar carrier dispersible or soluble polymers. If utilized, the amount of polymer or water dispersible materials normally ranges from about 0 wt.% to about 10 wt.%. Examples of polymers or water dispersible materials that can be employed in the medium comprise at least  
15 one member selected from the group of acrylic copolymers (supplied commercially as Carbopol®), hydroxyethyl cellulose, clays such as bentonite, fumed silica, among others.

In an aspect of the invention, the medium is modified to include at least one dopant material. The dopants can be useful for building additional thickness of the  
20 deposited layer. The amount of dopant can vary depending upon the properties of the dopant and desired results. Typically, the amount of dopant will range from about 0.001 wt.% to about 5 wt.% (or greater so long as the deposition rate is not adversely affected). Examples of suitable dopants comprise at least one member selected from the group of water soluble salts, oxides and precursors of tungsten,  
25 molybdenum, titanium (titatantes), zircon, vanadium, phosphorus, aluminum (aluminates), iron (e.g., iron chloride), boron (borates), bismuth, gallium, tellurium, germanium, antimony, niobium (also known as columbium), magnesium and manganese, sulfur, zirconium (zirconates) mixtures thereof, among others, and usually, salts and oxides of aluminum and iron, and other water  
30 soluble or dispersible monovalent species. The dopant can comprise at least one of molybdenic acid, fluorotitanic acid and salts thereof such as titanium hydrofluoride, ammonium fluorotitanate, ammonium fluorosilicate and sodium fluorotitanate; fluoro-zirconic acid and salts thereof such as  $H_2ZrF_6$ ,  $(NH_4)_2ZrF_6$  and  $Na_2ZrF_6$ ; among others. Alternatively, dopants can comprise at least one  
35 substantially water insoluble material such as electrophoretic transportable polymers, PTFE, boron nitride, silica, silicon carbide, silicon nitride, aluminum nitride, titanium carbide, diamond, titanium diboride, tungsten carbide, metal oxides such as cerium oxide, powdered metals and metallic precursors such as zinc, among others.

The aforementioned dopants can be employed for enhancing mineral layer formation rate, modifying the chemistry and/or physical properties of the resultant layer, as a diluent for the medium, among others. Examples of such dopants are iron salts (ferrous chloride, sulfate, nitrate), aluminum fluoride, fluorosilicates (e.g.,  $K_2SiF_6$ ), fluoroaluminates (e.g., potassium fluoroaluminate such as  
45  $K_2AlF_5 \cdot H_2O$ ), mixtures thereof, among other sources of metals and halogens. The dopant materials can be introduced to the metal surface in pretreatment steps, in post treatment steps (e.g., rinse), and/or by alternating exposing the metal

5 surface to solutions of dopants and solutions of the medium. The presence of  
dopants in the medium can be employed to form tailored surfaces upon the metal,  
e.g., an aqueous solution containing aluminate can be employed to form a layer  
comprising oxides of boron and aluminum. That is, at least one dopant (e.g., zinc)  
can be co-deposited along with at least one water soluble species (e.g., a mineral)  
10 upon the substrate.

The medium can also be modified by adding at least one diluent. Examples  
of suitable diluent comprise at least one member selected from the group of  
sodium sulphate, surfactants, de-foamers, colorants/dyes, conductivity modifiers,  
among others. The diluent (e.g., sodium sulfate) can be employed for reducing the  
15 affects of contaminants entering the medium, reducing bath foam, among others.  
When the diluent is employed as a defoamer, the amount normally comprises less  
than about 5 wt.% of the medium, e.g., about 1 to about 2 wt.%.

In some cases the effectiveness of the deposition can be improved by  
introducing an electrical current into the medium. The metal surface can be  
20 employed as either the anode or cathode (e.g., as described in aforementioned U.S.  
Patent Application Serial No. 09/814,641). Typically, when the medium is acidic  
the metal surface comprises the anode whereas for basic mediums the metal  
surface comprises the cathode. The current and voltage can be varied but  
normally the conditions are such that hydrogen evolves from the cathode and  
25 oxygen from the anode.

Contact with the inventive medium can be preceded by and/or followed  
with conventional pre-treatments and/or post-treatments known in this art such as  
cleaning or rinsing, e.g., immersion/spray within the treatment, sonic cleaning,  
double counter-current cascading flow; alkali or acid treatments, among other  
30 treatments. By employing a suitable post- or pre-treatment the solubility,  
corrosion resistance (e.g., reduced white rust formation when treating zinc  
containing surfaces), sealer and/or topcoat adhesion, among other properties of  
surface of the substrate formed by the inventive method can be improved. If  
desired, the post-treated surface can be sealed, rinsed and/or topcoated, e.g., silane,  
35 epoxy, latex, fluoropolymer, acrylic, among other coatings.

In one aspect of the invention, a pre-treatment comprises exposing the  
substrate to be treated to at least one of an acid, oxidizer, a basic solution (e.g.,  
zinc and sodium hydroxide) among other compounds. The pre-treatment can be  
employed for removing excess oxides or scale, equipotentialize the surface for  
40 subsequent mineralization treatments, convert the surface into a mineral precursor,  
among other benefits. Conventional methods for acid cleaning metal surfaces are  
described in ASM, Vol. 5, Surface Engineering (1994), and U.S. Patent No.  
6,096,650; hereby incorporated by reference.

In one aspect of the invention, the metal surface is pre-treated or cleaned  
45 electrolytically by being exposed to an anodic environment. That is, the metal  
surface is exposed to the medium wherein the metal surface is the anode and a  
current is introduced into the medium. By using the metal as the anode in a DC

5 cell and maintaining a current of about 10A/ft<sup>2</sup> to about 150A/ft<sup>2</sup>, the process can generate oxygen gas. The oxygen gas agitates the surface of the workpiece while oxidizing the substrate's surface. The surface can also be agitated mechanically by using conventional vibrating equipment. If desired, the amount of oxygen or other gas present during formation of the mineral layer can be increased by  
10 physically introducing such gas, e.g., bubbling, pumping, among other means for adding gases.

If desired, the inventive method can include a thermal post-treatment. The metal surface can be removed from the silicate medium, dried (e.g., at about 120 to about 150°C for about 2.5 to about 10 minutes), rinsed in deionized water and  
15 then dried. The dried surface may be processed further as desired; e.g. contacted with a sealer, rinse or topcoat. In an aspect of the invention, the thermal post treatment comprises heating the surface. Typically the amount of heating is sufficient to consolidate or densify the inventive surface without adversely affecting the physical properties of the underlying metal substrate. Heating can  
20 occur under atmospheric conditions, within a nitrogen containing environment, among other gases. Alternatively, heating can occur in a vacuum. The surface may be heated to any temperature within the stability limits of the surface coating and the surface material. Typically, surfaces are heated from about 75° C to about 250° C, more typically from about 120° C to about 200° C. If desired, the heat  
25 treated component can be rinsed in water to remove any residual water soluble species and then dried again (e.g., dried at a temperature and time sufficient to remove water).

In one aspect of the invention, a post treatment comprises exposing the substrate to a source of at least one carbonate or precursors thereof. Examples of  
30 carbonate comprise at least one member from the group of gaseous carbon dioxide, lithium carbonate, lithium bicarbonate, sodium carbonate, sodium bicarbonate, potassium carbonate, potassium bicarbonate, rubidium carbonate, rubidium bicarbonate, rubidium acid carbonate, cesium carbonate, ammonium carbonate, ammonium bicarbonate, ammonium carbamate and ammonium  
35 zirconyl carbonate. Normally, the carbonate source will be water soluble. In the case of a carbonate precursor such as carbon dioxide, the precursor can be passed through a liquid (including the medium) and the substrate immersed in the liquid. One specific example of a suitable posttreatment is disclosed in U.S. Patent No. 2,462,763; hereby incorporated by reference. Another specific example of a post  
40 treatment comprises exposing a treated surface to a solution obtained by diluting ammonium zirconyl carbonate (1:4) in distilled water (e.g., Bacote® 20 supplied by Magnesium Elektron Corp). If desired, the surface treated by the inventive process is dried and, then, post-treated with a carbonate (e.g., zirconyl ammonium carbonate). Further in some case, a carbonate post treated surface can be  
45 topcoated (e.g., aqueous or water borne topcoats).

In another aspect of the invention, the post treatment comprises heating the surface. Typically the amount of heating is sufficient to densify the inventive



5 surface without adversely affecting the physical properties of the underlying metal  
substrate. Heating can occur under atmospheric conditions, within a nitrogen  
containing environment, among other gases. If desired, prior to heating the  
inventive surface can be contacted with a solution containing a material that  
10 interacts with the surface at elevated temperatures, e.g., a eutectic formed between  
the metal surface and at least one of silica, alumina, B<sub>2</sub>O<sub>3</sub>, iron oxide, MgO,  
among other compounds. Normally, the heating will be sufficient to cause  
sintering or a desirable interaction without adversely affecting the underlying  
metal.

15 In another aspect of the invention, the post treatment comprises exposing  
the substrate to a source comprising at least one acid source or precursors thereof.  
Examples of suitable acid sources comprise at least one member chosen from the  
group of phosphoric acid, hydrochloric acid, molybdic acid, silicic acid, acetic  
acid, citric acid, nitric acid, hydroxyl substituted carboxylic acid, glycolic acid,  
20 lactic acid, malic acid, tartaric acid, ammonium hydrogen citrate, ammonium  
bifluoride, fluoboric acid, fluorosilicic acid, among other acid sources effective at  
improving at least one property of the treated metal surface. The Ph of the acid  
post treatment may be modified by employing at least one member selected from  
the group consisting of ammonium citrate dibasic (available commercially as  
Citrosol® #503 and Multiprep®), fluoride salts such as ammonium bifluoride,  
25 fluoboric acid, fluorosilicic acid, among others. The acid post treatment can serve  
to activate the surface thereby improving the effectiveness of rinses, sealers and/or  
topcoatings (e.g., surface activation prior to contacting with a sealer can improve  
cohesion between the surface and the sealer thereby improving the corrosion  
resistance of the treated substrate). Normally, the acid source will be water  
30 soluble and employed in amounts of up to about 15 wt.% and typically, about 1 to  
about 5 wt.% and have a Ph of less than about 5.5.

In another aspect of the invention, the post treatment comprises contacting  
a surface treated by the inventive process with a rinse. By "rinse" it is meant that  
an article or a treated surface is sprayed, dipped, immersed or other wise exposed  
35 to the rinse in order to affect the properties of the treated surface. For example, a  
surface treated by the inventive process is immersed in a bath comprising at least  
one rinse. In some cases, the rinse can interact or react with at least a portion of  
the treated surface. Further the rinsed surfaced can be modified by multiple rinses,  
heating, topcoating, adding dyes, lubricants and waxes, among other processes.  
40 Examples of suitable compounds for use in rinses comprise at least one member  
selected from the group of titanates, titanium chloride, tin chloride, zirconates,  
zirconium acetate, zirconium oxychloride, fluorides such as calcium fluoride, tin  
fluoride, titanium fluoride, zirconium fluoride; coppurous compounds, ammonium  
fluorosilicate, metal treated silicas (e.g., Ludox®), nitrates such as aluminum  
45 nitrate; sulphates such as magnesium sulphate, sodium sulphate, zinc sulphate, and  
copper sulphate; lithium compounds such as lithium acetate, lithium bicarbonate,  
lithium citrate, lithium metaborate, lithium vanadate, lithium tungstate, among

5 others. The rinse can further comprise at least one organic compound such as  
vinyl acrylics, fluorosurfactants, polyethylene wax, among others. Examples of  
commercially available sealers, rinses and topcoats comprise at least one member  
selected from the group of Aqualac® (urethane containing aqueous solution),  
W86®, W87®, B37®, T01®, E10®, B17, B18 among others (a heat cured coating  
10 supplied by the Magni® Group), JS2030S (sodium silicate containing rinse  
supplied by MacDermid Incorporated), JS2040I (a molybdenum containing rinse  
also supplied by MacDermid Incorporated), EnSeal® C-23 (an acrylic based  
coating supplied by Enthone), EnSeal® C-26, Enthone® C-40 (a pigmented  
coating supplied by Enthone), Microseal®, Paraclene® 99 (a chromate containing  
15 rinse), EcoTri® (a silicate/polymer rinse), MCI Plus OS (supplied by Metal  
Coatings International), silanes (e.g., Dow Corning Z-6040, Gelest SIA 0610.0,  
among others), ammonium zirconyl carbonate (e.g., Bacote 20), urethanes (e.g.,  
Agate L18), among others. One specific rinse comprises water, water dispersible  
urethane, and at least one silicate, e.g., refer to commonly assigned U.S. Patent  
20 No. 5,871,668; hereby incorporated by reference. While the rinse can be  
employed neat, normally the rinse will be dissolved, diluted or dispersed within  
another medium such as water, organic solvents, among others. While the amount  
of rinse employed depends upon the desired results, normally the rinse comprises  
about 0.1 wt% to about 50 wt.% of the rinse medium. The rinse can be employed  
25 as multiple applications and, if desired, heated. Moreover, the aforementioned  
rinses can be modified by incorporating at least one dopant, e.g. the  
aforementioned dopants. The dopant can be employed for interacting or reacting  
with the treated surface. If desired, the dopant can be dispersed in a suitable  
medium such as water and employed as a rinse.

30 The inventive process can create a flexible surface that can survive  
secondary processes, e.g., metal deformation for riveting, swaging, crimping,  
among other processes, and continue to provide corrosion protection. Such is in  
contrast to typical corrosion inhibitors such as chromates that tend to crack when  
the underlying surface is shaped. If desired, the surface formed by the inventive  
35 process can be topcoated (e.g, with a heat cured epoxy), prior to secondary  
processing. Articles treated in accordance with the inventive process, topcoated  
and exposed to a secondary process retain their desirable corrosion resistance,  
coating adhesion, component functionality, among properties.

40 The inventive process can provide a surface (e.g., mineral coating) that can  
enhance the surface characteristics of the metal or conductive surface such as  
resistance to corrosion, protect carbon (fibers for example) from oxidation, stress  
crack corrosion (e.g., stainless steel), hardness, thermal resistance, improve  
bonding strength in composite materials, provide dielectric layers, improve  
corrosion resistance of printed circuit/wiring boards and decorative metal finishes,  
45 and reduce the conductivity of conductive polymer surfaces including application  
in sandwich type materials.

5 The mineral coating can also affect the electrical and magnetic properties of  
the surface. That is, the mineral coating can impart electrical resistance or  
insulative properties to the treated surface. By having an electrically non-  
conductive surface, articles having the inventive layer can reduce, if not eliminate,  
10 electro-galvanic corrosion in fixtures wherein current flow is associated with corrosion,  
e.g., bridges, pipelines, among other articles.

Depending upon the intended usage of the workpiece treated by the  
inventive method, the workpiece can be coated with a secondary coating or layer.  
Alternatively, the treated workpiece can be rinsed (as described above) and then  
coated with a secondary coating or layer. Examples of such secondary coatings or  
15 layers comprise one or more members of acrylic coatings (e.g., IRILAC®),  
e-coats, silanes including those having amine, acrylic and aliphatic epoxy  
functional groups, latex, urethane, epoxies, silicones, alkyds, phenoxy resins  
(powdered and liquid forms), radiation curable coatings (e.g., UV curable  
coatings), lacquer, shellac, linseed oil, among others. Secondary coatings can be  
20 solvent or water borne systems. The secondary coatings can be applied by using  
any suitable conventional method such as immersing, dip-spin, spraying, among  
other methods. The secondary coatings can be cured by any suitable method such  
as UV exposure, heating, allowed to dry under ambient conditions, among other  
methods. An example of UV curable coating is described in U.S. Patent Nos.  
25 6,174,932 and 6,057,382; hereby incorporated by reference. Normally, the surface  
formed by the inventive process will be rinsed, e.g., with at least one of deionized  
water, silane or a carbonate, prior to applying a topcoat. The secondary coatings  
can be employed for imparting a wide range of properties such as improved  
corrosion resistance to the underlying mineral layer, reduce torque tension, a  
30 temporary coating for shipping the treated workpiece, decorative finish, static  
dissipation, electronic shielding, hydrogen and/or atomic oxygen barrier, among  
other utilities. The mineral coated metal, with or without the secondary coating,  
can be used as a finished product or a component to fabricate another article.

The thickness of the rinse, sealer and/or topcoat can range from about  
35 0.00001 inch to about 0.025 inch. The selected thickness varies depending upon  
the end use of the coated article. In the case of articles having close dimensional  
tolerances, e.g., threaded fasteners, normally the thickness is less than about  
0.00005 inch.

In another aspect, the treated metal surface is contacted with a secondary  
40 coating. Examples of such secondary coatings and methods that can be  
complimentary to the instant invention are described in U.S. Patent Nos.  
5,759,629; 5,750,197; 5,539,031; 5,498,481; 5,478,655; 5,455,080; and 5,433,976.  
The disclosure of each of these U.S. Patents is hereby incorporated by reference.  
For example, improved corrosion resistance of a metal substrate can be achieved  
45 by using a secondary coating comprising at least one suitable silane (e.g., in the  
medium, rinse, sealer and/or topcoat) in combination with a mineralized surface.  
Examples of suitable silanes comprise at least one members selected from the

5 group consisting of tetra-ortho-ethyl-silicate (TEOS), bis-1,2-(triethoxysilyl)  
ethane (BSTE), vinyl silane or aminopropyl silane, epoxy silanes,  
vinyltriactosilane, alkoxysilanes, among other organo functional silanes. The  
silane can bond with the mineralized surface and then the silane can cure thereby  
providing a protective top coat, or a surface for receiving an outer coating or layer.  
10 In some cases, it is desirable to sequentially apply the silanes. For example, a steel  
substrate, e.g., a fastener, can be treated by the inventive process to form a mineral  
layer, allowed to dry, rinsed in deionized water, coated with a 5% BSTE solution,  
coated again with a 5% vinyl silane solution, and powder coated with a thermoset  
epoxy paint (Corvel 10-1002 by Morton) at a thickness of 2 mils.

15 The inventive process forms a surface that may have improved adhesion to  
outer coatings or layers, e.g., secondary coatings. Examples of suitable outer  
coatings comprise at least one member selected from the group consisting of  
acrylics, epoxies, e-coats, latex, urethanes, silanes (e.g., TEOS, MEOS, among  
others), fluoropolymers, alkyds, silicones, polyesters, oils, gels, grease, among  
20 others. An example of a suitable epoxy comprises a coating supplied by The  
Magni® Group as B17 or B18 top coats, e.g, a galvanized article that has been  
treated in accordance with the inventive method and contacted with at least one  
silane and/or ammonium zirconium carbonate and top coated with a heat cured  
epoxy (Magni® B18) thereby providing a chromate free corrosion resistant article.  
25 By selecting appropriate rinses, secondary and outer coatings for application upon  
the mineral, a corrosion resistant article can be obtained without chromating or  
phosphating. Such a selection can also reduce usage of zinc to galvanize iron  
containing surfaces, e.g., a steel surface is mineralized, coated with a silane  
containing coating and with an outer coating comprising an epoxy.

30 Without wishing to be bound by any theory or explanation, it is believed  
that the inventive process forms a surface that can release or provide water or  
related moieties. These moieties can participate in a hydrolysis or condensation  
reaction that can occur when an overlying rinse, seal or topcoating cures. Such  
participation improves the cohesive bond strength between the surface and  
35 overlying cured coating.

The surface formed by the inventive process can also be employed as an  
intermediate or tie-layer for glass coatings, glass to metal seals, hermetic sealing,  
among other applications wherein it is desirable to have a joint or bond between a  
metallic substrate and a glass layer or article. The inventive surface can serve to  
40 receive molten fluids (e.g., zinc, aluminum, steel, borosilicate, aluminosilicate,  
phosphate, among other glasses), while protecting the underlying metallic  
substrate and forming a seal.

The inventive process can provide a surface that improves adhesion  
between a treated substrate and an adhesive. Examples of adhesives comprise at  
45 least one member selected from the group consisting of hot melts such as at least  
one member selected from the group of polyamides, polyimides, butyls, acrylic  
modified compounds, maleic anhydride modified ethyl vinyl acetates, maleic

5 anhydride modified polyethylenes, hydroxyl terminated ethyl vinyl acetates,  
carboxyl terminated ethyl vinyl acetates, acid terpolymer ethyl vinyl acetates,  
ethylene acrylates, single phase systems such as dicyanamide cure epoxies,  
polyamide cure systems, lewis acid cure systems, polysulfides, moisture cure  
urethanes, two phase systems such as epoxies, activated acrylates polysulfides,  
10 polyurethanes, among others. Two metal substrates having surfaces treated in  
accordance with the inventive process can be joined together by using an adhesive.  
Alternatively one substrate having the inventive surface can be adhered to another  
material, e.g., joining treated metals to plastics, ceramics, glass, among other  
surfaces. In one specific aspect, the substrate comprises an automotive hem joint  
15 wherein the adhesive is located within the hem.

The improved cohesive and adhesive characteristics between a surface  
formed by the inventive process and polymeric materials can permit forming  
acoustical and mechanical dampeners, e.g., constraint layer dampers such as  
described in U.S. Patent No. 5,678,826 hereby incorporated by reference, motor mounts,  
20 bridge/building bearings, HVAC silencers, highway/airport sound barriers, among other  
articles. The ability to improve the bond between viscoelastic materials  
sandwiched between metal panels in dampers reduces sound transmission,  
improves formability of such panels, reduces process variability, among other  
improvements. The metal panels can comprise any suitable metal such as 304  
25 steel, stainless steel, aluminum, cold rolled steel, zinc alloys, hot dipped zinc or  
electrogalvanized, among other materials. Examples of polymers that can be  
bonded to the inventive surface and in turn to an underlying metal substrate  
comprise any suitable material such as neoprene, EPDM, SBR, EPDM, among  
others. The inventive surface can also provide elastomer to metal bonds described  
30 in U.S. Patent No. 5,942,333; hereby incorporated by reference.

The inventive process can employ dopants, rinses, sealers and/or topcoats  
for providing a surface having improved thermal and wear resistance. Such  
surfaces can be employed in gears (e.g., transmission), powdered metal articles,  
exhaust systems including manifolds, metal flooring/grates, heating elements,  
35 among other applications wherein it is desirable to improve the resistance of  
metallic surfaces.

In another aspect of the invention, the inventive process can be used to  
produce a surface that reduces, if not eliminates, molten metal adhesion (e.g., by  
reducing intermetallic formation). Without wishing to be bound by any theory or  
40 explanation, it is believed that the inventive process provides an ablative and/or a  
reactive film or coating upon an article or a member that can interact or react with  
molten metal thereby reducing adhesion to the bulk article. For example, the  
inventive process can provide an inorganic iron or a zinc containing film or layer  
upon a substrate in order to shield or isolate the substrate from molten metal  
45 contact (e.g., molten aluminum or magnesium). The effectiveness of the film or  
layer can be improved by applying an additional coating comprising silica (e.g., to  
function as an ablative when exposed to molten metal). The ability to prevent

5 molten metal adhesion is desirable when die casting aluminum or magnesium over  
zinc cores, die casting aluminum for electronic components, among other uses.  
The molten metal adhesion can be reduced further by applying one of the  
aforementioned topcoatings, e.g. Magni® B18, acrylics, polyesters, among others.  
10 The topcoatings can be modified (e.g., to be more heat resistant) by adding a heat  
resistant material such as colloidal silica (e.g., Ludox® which can also be added to  
the medium and rinse).

While the above description places particular emphasis upon forming a  
mineral containing layer upon a metal surface, the inventive process can be  
combined with or replace conventional metal pre or post treatment and/or  
15 finishing practices. Conventional post coating baking methods can be employed  
for modifying the physical characteristics of the mineral layer, remove water  
and/or hydrogen, among other modifications. The inventive mineral layer can be  
employed to protect a metal finish from corrosion thereby replacing conventional  
phosphating process, e.g., in the case of automotive metal finishing the inventive  
20 process could be utilized instead of phosphates and chromates and prior to coating  
application e.g., E-Coat. The inventive process can be employed for imparting  
enhanced corrosion resistance to electronic components. The inventive process  
can also be employed in a virtually unlimited array of end-uses such as in  
conventional plating operations as well as being adaptable to field service. For  
25 example, the inventive mineral containing coating can be employed to fabricate  
corrosion resistant metal products that conventionally utilize zinc as a protective  
coating, e.g., automotive bodies and components, grain silos, bridges, among  
many other end-uses. Moreover, depending upon the dopants and concentration  
thereof present in the mineral deposition solution, the inventive process can  
30 produce microelectronic films, e.g., on metal or conductive surfaces in order to  
impart enhanced electrical/magnetic (e.g., EMI shielding, reduced electrical  
connector fretting, reduce corrosion caused by dissimilar metal contact, among  
others), and corrosion resistance, or to resist ultraviolet light and monotomic  
oxygen containing environments such as outer space.

35 The following Examples are provided to illustrate certain aspects of the  
invention and it is understood that such an Example does not limit the scope of the  
invention.

## 40 EXAMPLES

The examples illustrate electroless deposition that was conducted in NaOH  
solution along with various oxygen containing water soluble compounds. All deposition  
studies were done at a Ph of 11 and temperature of 75°C. The mineralization process was  
done on bare steel, Sn plated steel, hot dip galvanized steel and electro-galvanized steel  
45 using the following solutions:

- 5
- Deposition in NaOH solution + 1 g/L sodium stannate trihydrate
  - Deposition in NaOH + 1 g/L sodium molybdate dihydrate
  - Deposition in NaOH solution + 1 g/L ammonium metavanadate
  - Deposition in NaOH solution + 1 g/L cerium nitrate hexahydrate

10 Subsequent to electroless deposition, the panels were removed from the bath and washed with deionized (DI) water immediately.

Next, the corrosion characteristics of the panel were studied in 0.5 M Na<sub>2</sub>SO<sub>4</sub> solution at Ph 4. A representative panel area of 1 cm<sup>2</sup> was chosen for testing. A three-electrode setup was used to study the corrosion behavior of the mineralized samples. The electrolyte used in this study is 0.5 M sodium sulfate, Ph=4. Ti coated with Pd was used as the counter electrode. Hg/Hg<sub>2</sub>SO<sub>4</sub> was used as the reference electrode. All potentials in this study are referred with respect to the Hg/Hg<sub>2</sub>SO<sub>4</sub> electrode. Corrosion studies were done using Scribner Associates Corrware Software with EG&G Princeton applied Model 273 potentiostat/galvanostat and a Solartron 1255 frequency analyzer. The electrode was left on open circuit till it's potential stabilized. After the potential stabilized, non-destructive evaluation of the surface was done using linear polarization and impedance analysis. During linear polarization, the potential was varied 10 Mv above and below the open circuit potential of the mineralized sample at a scan rate of 0.1667 Mv/s. The impedance data generally covered a frequency range of 5 mHz to 10 kHz. A sinusoidal ac voltage signal varying by  $\pm 10$  Mv was applied. The electrode was stable during the experiments and its open circuit potential changed less than 1 Mv.

The results of the corrosion studies are detailed below in Tables 1-3.

**Table 1. Corrosion Resistance for Samples Immersed in NaOH + Sodium Stannate Solution**

Substrate	Specimen #	Rp ( $\Omega$ -cm <sup>2</sup> )				Rp - Avg ( $\Omega$ -cm <sup>2</sup> )
Fe-Sn	1	365106	316867	356816	542530	395329.8
Steel (Fe)	2	4194	5136	3718	5061	4527.25
Steel (Fe)	3	4807	8061	13443	754	6766.25
Galvalume	4	1111	1516	1374	854	1213.75

<b>Galvalume</b>	5	1596	1886	1395	678	1388.75
<b>Fe-Zn</b>	6	1009	330	852	935	781.5
<b>Fe-Zn</b>	7	1601	750	902	355	902

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**Table 2. Corrosion Resistance for Samples Immersed in NaOH + Sodium Molybdate Solution**

<b>Substrate</b>	<b>Specimen #</b>	<b>Rp (<math>\Omega\text{-cm}^2</math>)</b>				<b>Rp – Avg (<math>\Omega\text{-cm}^2</math>)</b>
<b>Fe-Sn</b>	1	139047	252466	378666	234211	251098
	2	20096	656490	331291	3121	252750
<b>Steel (Fe)</b>	3	841	1186	994	817	959.5
<b>Steel (Fe)</b>	4	1478	794	1120	885	1069.25
<b>Galvalume</b>	5	2567	1957	1496	1846	1966.5
<b>Galvalume</b>	6	2120	2013	2173	1553	1964.75
<b>Fe-Zn</b>	7	870	816	779	798	815.75
<b>Fe-Zn</b>	8	959	1181	834	1150	1031

**Table 3. Corrosion Resistance for Samples Immersed in NaOH + Cerium Nitrate**

<b>Substrate</b>	<b>Specimen #</b>	<b>Rp (<math>\Omega\text{-cm}^2</math>)</b>				<b>Rp – Avg (<math>\Omega\text{-cm}^2</math>)</b>
<b>Fe-Sn</b>	1	50861	170332	46192	20867	72063
	2	36760	76518	140604	53238	76780
<b>Steel (Fe)</b>	3	747	495	848	947	759.25
<b>Steel (Fe)</b>	4	544	1323	629	1269	941.25
<b>Galvalume</b>	5	838	364	1329	947	869.5
<b>Galvalume</b>	6	1363	1214	1354	879	1202.5
<b>Fe-Zn</b>	7	1065	1074	1344	947	1107.5
<b>Fe-Zn</b>	8	723	682	846	663	728.5

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